A proposed practical model for zoning with the Avalanche Terrain Exposure Scale

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ABSTRACT: Since 2009, the Avalanche Terrain Exposure Scale (ATES) has been used to zone avalanche terrain in western Canada and many other alpine nations. Despite this widespread use, technical specifications for the use of ATES zoning have been lacking. This paper proposes a practical model for delineating ATES zones with standardized specifications and methodologies. An example of the use of the model is presented in a case study in the Fraser Lake area of northwest British Columbia. The ATES zoning model is the first attempt at developing parameters and thresholds specifically for zoning avalanche terrain with ATES. As ATES zoning becomes more widely utilized, a designated model is necessary to establish common practices, consistent methodologies, and uniform criteria.

KEYWORDS: ATES, avalanche, terrain, zoning, model.

1 INTRODUCTION

The Avalanche Terrain Exposure Scale (ATES) was first introduced in 2004 to classify backcountry recreational trips in terms of overall exposure to avalanche terrain (Statham et al., 2006). It was initially intended to serve as a text rating for an individual route or drainage; however, as stated in a concluding remark: "ultimately the visualization of ATES ratings on terrain maps is the next logical step" (Statham et al., 2006).

In 2009, ATES started to emerge as a classification system for zoning avalanche terrain (Campbell and Marshall, 2010). Since then, ATES zoning methodology has been refined and used extensively in western Canada, as well as been adopted in many other alpine nations (Campbell et al., 2012). In western Canada alone, over 8000 km^2 has been zoned for recreational or workplace safety purposes.

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Despite widespread use, technical specifications for ATES zoning have yet to be developed. To date, all zoning in Canada has been based on the ATES Technical Model v.1/04 (Statham et al., 2006) using methods described by Campbell et al. (2012).

2 OBJECTIVES

The objectives of this paper are to propose a model for zoning avalanche terrain that is:

- Accessible (doesn't require specialized computer applications);
- Comprehensive but not overcomplicated;
- Compatible with the ATES Technical Model v.1/04 (Statham et al., 2006), while reducing the subjectivity of the parameters as much as possible;
- Applicable at an appropriate scale for trip planning purposes; and
- Based on the analysis of previously zoned terrain for the two primary avalanche terrain parameters: slope incline and forest density (Delparte, 2008).

3 ANALYSIS OF SLOPE INCLINE AND FOREST DENSITY PARAMETERS

Forest density and slope incline relationships were analysed for over 2000 km^2 of zoned avalanche terrain spanning the four major mountain ranges in British Columbia, Canada (Campbell and Gould, in progress). All terrain included in the analysis was zoned according to the methods described by Campbell et al. (2012) at a scale of 100 – 1000 m. The results of the analysis for Class 1, 2, and 3 zones are incorporated into the slope incline and forest density thresholds utilized in the proposed model as presented in Table 1.

4 PROPOSED MODEL

The proposed model for delineating ATES zones is outlined in Table 1. The parameters are listed in the table generally in order of importance, with the intent of placing more emphasis on the top two or three parameters. Zones should be delineated in such a way that uses the lowest class possible (except Class 0, which is optional) at a scale of 100 – 1000 m.

Zoning with this model usually begins with Geographical Information System (GIS) analysis followed by detailed field surveys. However, terrain can often be reliably zoned using a combination of these and other resources, such as topographic maps, air photos, and expert judgment informed by intimate knowledge of the terrain. Detailed methods for preliminary zoning and field surveys are described in Campbell et al. (2012).

5 ACCURACY

The level of accuracy required for ATES zones often depends on the intended application. For recreational trip planning purposes, a high level of accuracy is often not needed because trip planning exercises usually involve only general overviews of the nature of the avalanche terrain. However, for operational decision support, a high level of accuracy may be required to maximize efficiency. Depending on the scale at which the zoning is presented, it is common to overlap zones to indicate that zone boundaries are not precise.

The highest accuracy can be achieved through GIS analysis and detailed field surveys. However, for straightforward terrain, high accuracy can often be achieved without field surveys, assuming high quality imagery and digital terrain models are available. For highly variable terrain, more detailed field surveys may be necessary to achieve reasonable accuracy.

6 MAPPING STANDARDS

In Canada, it is normal practice to present ATES zoning in web-based maps. In addition, 1:20,000 to 1:50,000 scale maps with ATES zones overlaid are common. Larger scale mapping is generally too detailed, although this may be considered for special applications. An ATES mapping colour scheme standard has emerged and is outlined in Table 2.

Table 2. Colour scheme for mapping with the Avalanche Terrain Exposure Scale.

Class	Colour
0	White or no colour
1	Green
2	Blue
3	Black or red

Table 1. Proposed model for zoning with the Avalanche Terrain Exposure Scale. Thresholds listed in **bold-type** are required for that particular zone classification.

		Class 0 (optional)	Class 1	Class 2	Class 3
Slope Incline[1] and Forest Density[2]	**Open**	**99% ≤ 20˚**	**90% ≤ 20˚ 99% ≤ 25˚**	**90% ≤ 30˚ 99% ≤ 40˚**	< 20% ≤ 25˚ 45% > 35˚
	Mixed	**99% ≤ 25˚**	**90% ≤ 25˚ 99% ≤ 35˚**	**90% ≤ 35˚ 99% ≤ 45˚**	
	Forest	**99% ≤ 30˚**	**99% ≤ 35˚**	**99% ≤ 45˚**	
Start Zone Density		**No start zones.**	**No start zones with ≥ Size 2 potential. Isolated start zones with < Size 2 potential.**	**No start zones with > Size 3 potential. Isolated start zones with ≤ Size 3 potential, or Several start zones with ≤ Size 2 potential.**	Numerous start zones of any size, containing several potential release zones.
Interaction with Avalanche Paths[3]		**No exposure to avalanche paths.**	**Beyond 10-year runout extent for paths with ≥ Size 2 potential.**	**Single path or paths with separation. Beyond annual runout extent for paths with > Size 3 potential.**	Numerous and overlapping paths of any size. Any position within path.
Terrain Traps[4]		**No potential for partial burial or any injury.**	**No potential for complete burial or fatal injury.**	**Potential for complete burial but not fatal injury.**	Potential for complete burial and fatal injury.
Slope Shape		Uniform or concave	Uniform	Convex	Convoluted

[1] Slope inclines are averaged over a fall-line distance of 20 - 30 m.
[2] Open: < 100 stems/ha or > 10.0 m tree spacing on average. Mixed: 100 – 1000 stems/ha or 3.2 – 10.0 m tree spacing on average. Forest: > 1000 stems/ha or < 3.2 m tree spacing on average.
[3] Position within paths based on the runout extent for avalanches with a specified return period.
[4] Terrain traps are features in tracks or runouts that increase the consequences of being caught in an avalanche. Thresholds are based on the potential increased consequences they would add to an otherwise harmless avalanche. For this purpose, terrain traps can be thought of as either trauma-type (e.g., cliffs, trees, boulders, etc.) or burial-type (e.g., depressions, abrupt transitions, open water, gullies, ravines, etc.). Degrees of burial used in this model are based on Canadian standard avalanche involvement definitions (Canadian Avalanche Association, 2009).

7 CASE STUDY

The Fraser Lake area in the northwest region of British Columbia was mapped with Class 1, 2 and 3 ATES zones (Figure 1). The first task was to delineate Class 1 and Class 3 zones using the Forest Density and Slope Incline thresholds (Table 1). These zones were manually delineated with the aid of satellite imagery, slope incline overlays, and forest cover overlays as outlined by Campbell et al. (2012). This could also be accomplished with a paper topographic map that includes forest cover, together with a slope incline transparency overlay.

All large open areas with slope incline steeper than 40° and mixed areas steeper than 45° were initially zoned Class 3 since 99% of the terrain must be less than these values for Class 2. All open terrain with incline less than 25° for open terrain and less than 20° for mixed or forested terrain were initially zoned Class 1. All areas in between these values were initially zoned as Class 2. Major avalanche paths could also be identified in the imagery, and zone boundaries within the trim lines were extended downslope such that the Class 1 boundary was approximately at the 30-year runout.

Following this preliminary zoning phase, a field survey was completed and local area experts were consulted. This phase focused on the other four parameters (Table 1), while paying close attention to required thresholds. Specific areas where the other parameters influenced zoning are indicated in Figure 1 and described below.

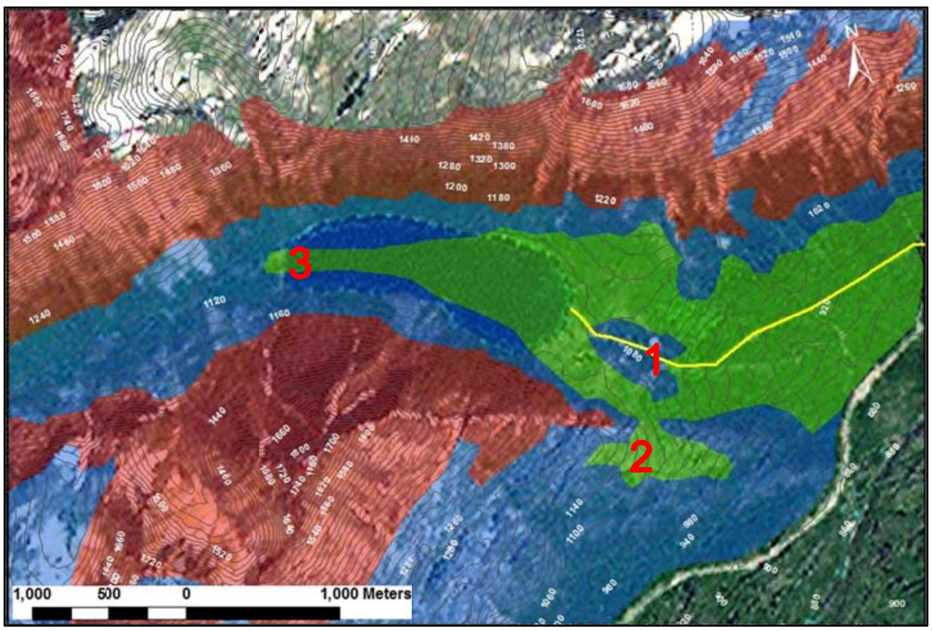

Figure 1. Map of the Fraser Lake area showing Class 1 (green), Class 2 (blue), and Class 3 (red) avalanche terrain. The summer road to the lake (yellow line) is also shown. Terrain with no shading was not zoned. Numbers indicate areas where zoning was refined after field surveying and discussions with local area experts.

1. This zone is a terrain trap (gully) that has the potential for complete burial in an otherwise harmless avalanche. It was difficult to estimate the potential consequences of the terrain trap during the initial zoning, consequently this area was initially zoned as Class 1. After a field survey and discussions with local area experts, this zone was updated to Class 2.
2. This area was zoned as Class 2 during the initial zoning, because although generally low-angled, it appeared to have steep pitches with abrupt transitions. After the field survey and discussion with local area experts the initial rating of Class 2 was downgraded to Class 1

as there were only Size 1 start zones, and no terrain traps that had the potential for complete burial.

3. The 10-year runout distances for the major avalanche paths on either side of this valley and Fraser Lake were underestimated during the initial zoning and the Class 1 corridor was initially zoned wider. After discussions with local area experts, it was determined that avalanches regularly run onto the lake, with 10 – 30 year return periods to the centre of the lake. As a result, the Class 1 corridor was narrowed and shortened.

Once the zones were adjusted with the results of the field survey and local area expert input, a GIS analysis was completed to ensure that all zones met the required thresholds for slope incline. The slope incline distributions for each zone are shown in Figures 2 and 3, and meet the required thresholds listed in Table 1.

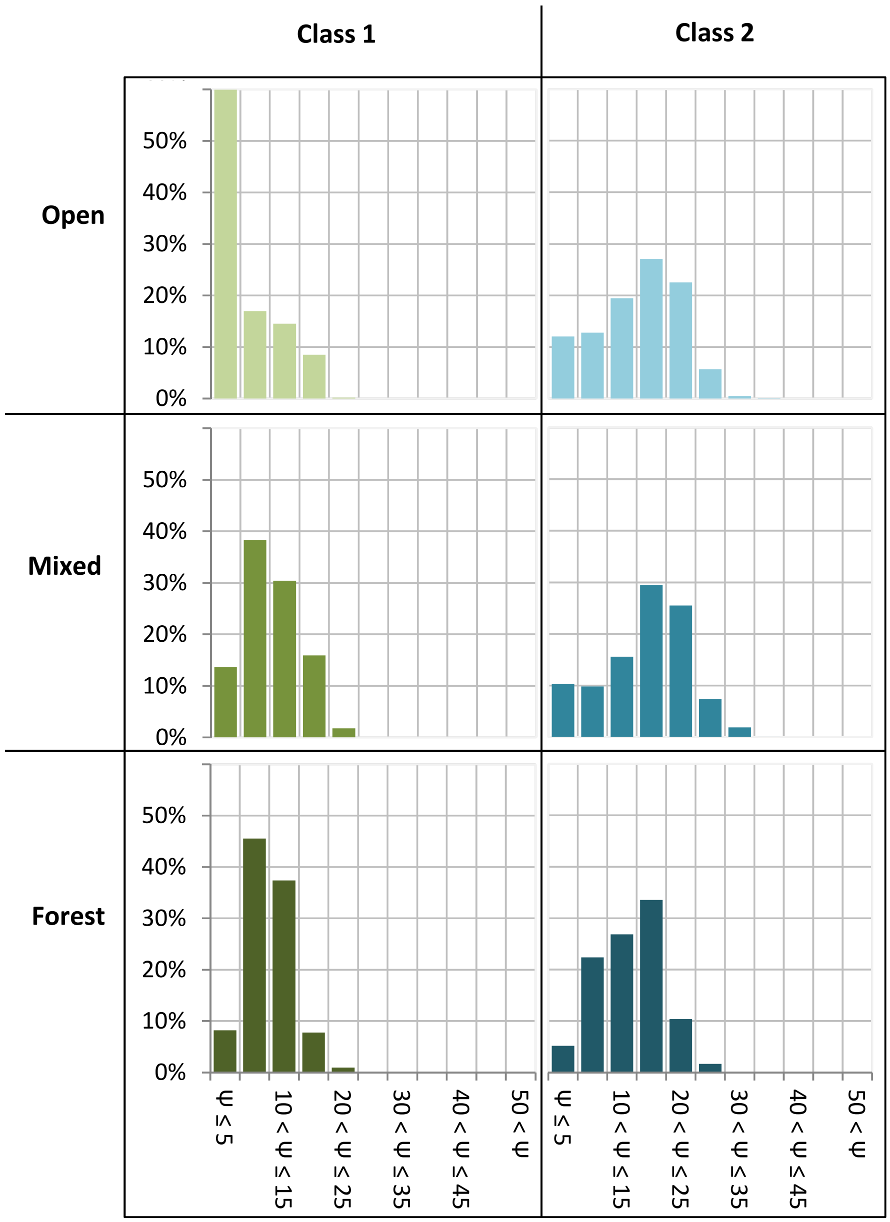

Figure 2. Histograms of slope incline (Ψ) for Open, Mixed, and Forest terrain in Class 1 and 2 zones in the Fraser Lake area.

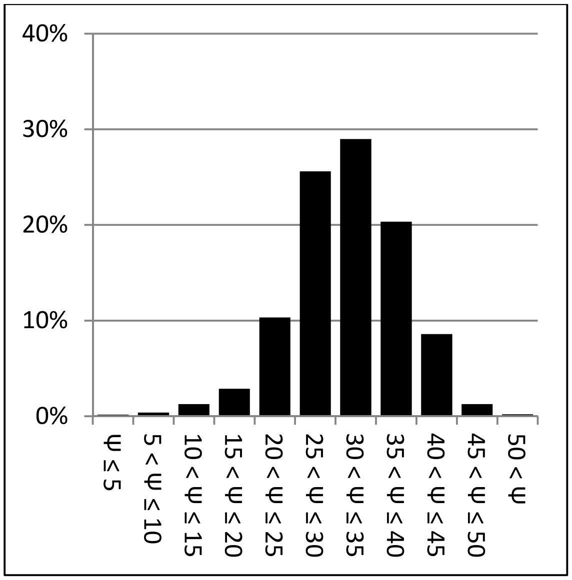

Figure 3 – Histogram of slope incline (Ψ) for Class 3 zones in the Fraser Lake area.

8 DISCUSSION AND CONCLUSIONS

The ATES zoning model presented in this paper represents an evolution of a time-tested public communication tool. This is the first attempt at developing parameters and thresholds specifically for zoning with ATES. This is also the first attempt at specifying thresholds for a non-avalanche terrain class.

This proposed model represents results from analysis of a large and representative sample of avalanche terrain in British Columbia zoned with methods described by Campbell et al. (2012). It also represents ideas developed during years of experience zoning with these methods.

One of the main considerations in developing this model was accessibility. This means that if necessary the model can be applied without the use of specialized computer application, or even computers, and helps to ensure that the model will become widely accepted and utilized. Another consideration for increased utility of the model was agreement with the ATES Technical Model v.1/04 (Statham et al., 2006) so that it would honor previously rated terrain. The scale also needs to be compatible with widely-used decision support systems based on ATES (e.g. Haegeli et al., 2006). Finally, widespread acceptance and utility requires that this model be applicable across all snow climates, and as such it needs to be entirely terrain-based.

In order for this model to be compatible with GIS applications an attempt was made to use parameters that could be digitally modelled and thresholds that were deterministic as possible. However, in order to be comprehensive and include all the important characteristics of avalanche terrain, assumptions must still be made for fully automated modelling.

We do not propose that this model replace the ATES Technical Model v.1/04, as that model works well for its intended purpose of guiding expert judgment in classifying a pre-determined route. But, as ATES zoning becomes more heavily utilized, a designated model and standards are necessary to establish common practice, consistent methodology, and uniform criteria.

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